Detection and Localization of Gravitational Wave Transients: The Early Years

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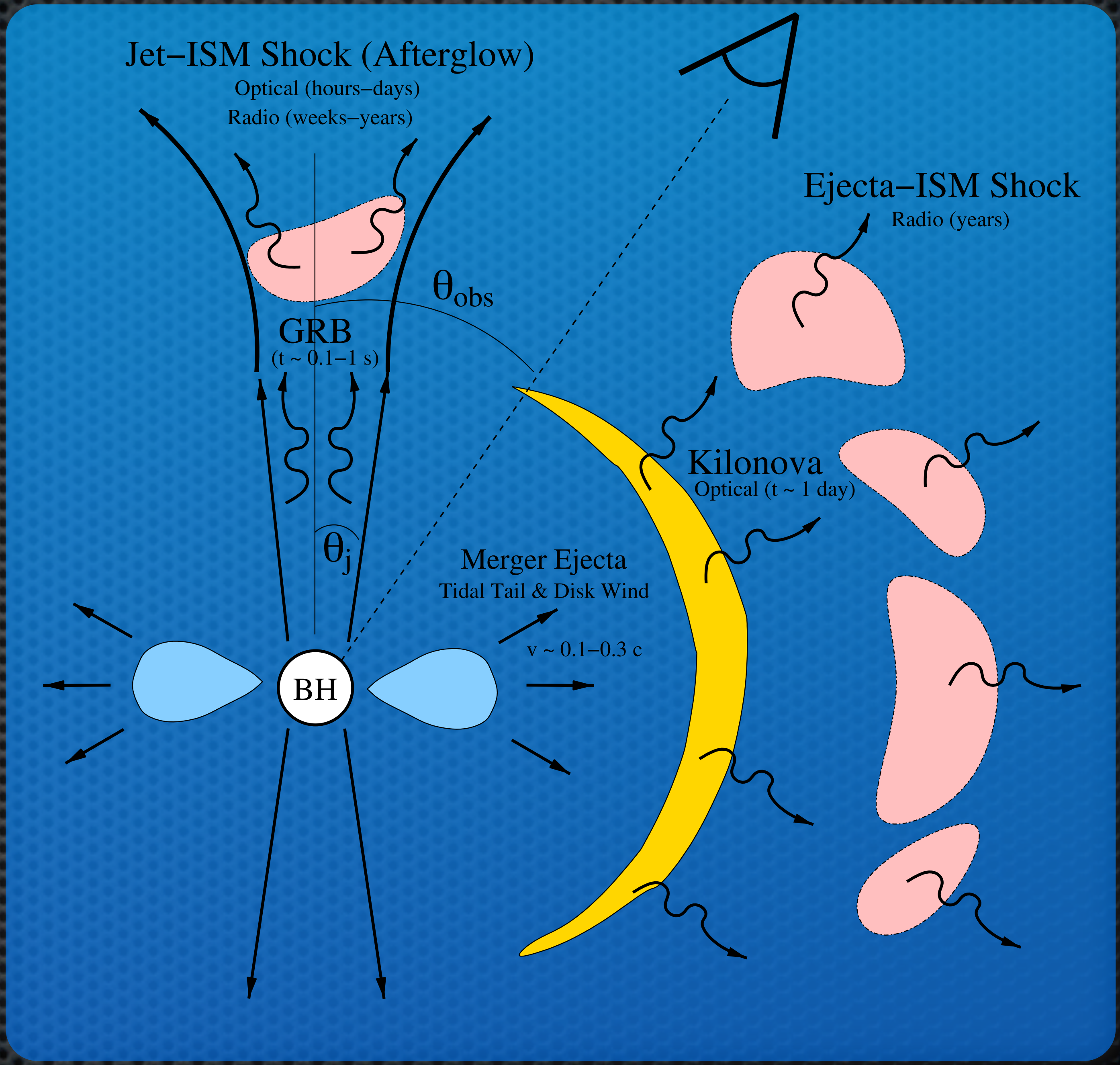
for the LIGO Scientific Collaboration

and the Virgo Collaboration

LIGO-G1300913

Motivation

- GWs inform us about the central engine
- EM informs us about location and environment



Metzger & Berger, ApJ 746, 48 (2012)

Two Types of EM+GW Searches

Credit: NASA

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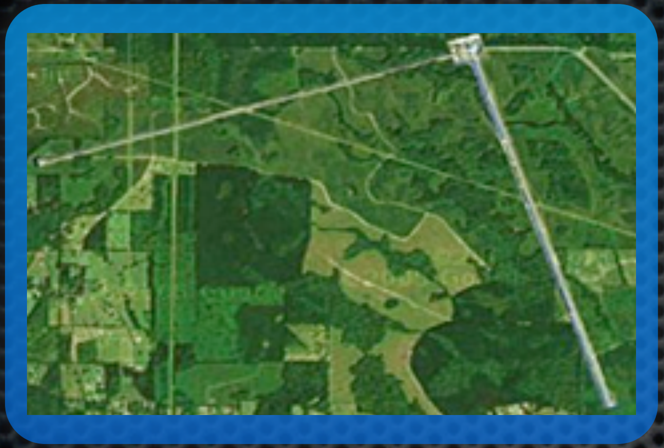
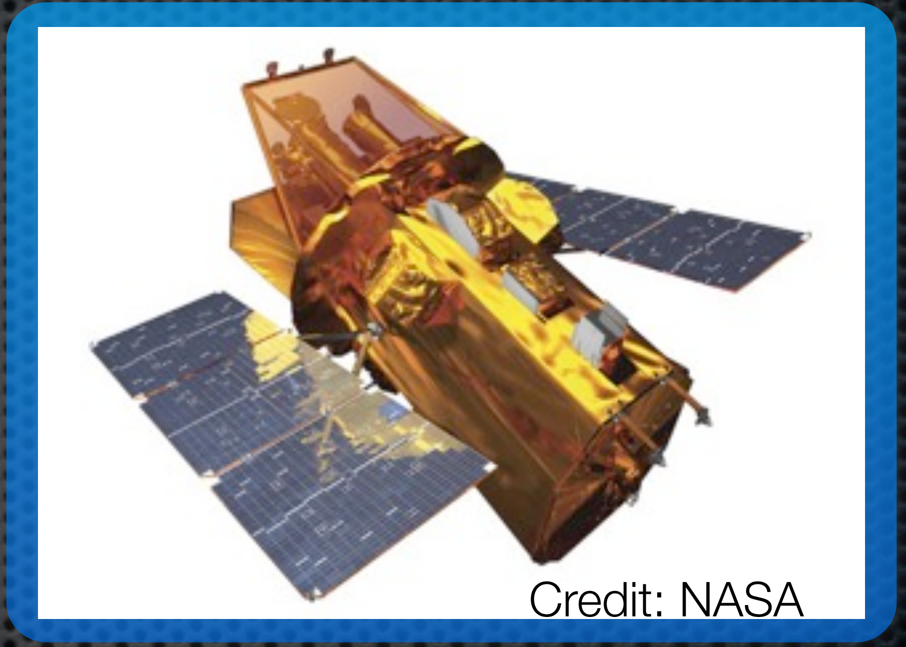
Credit: ROTSE

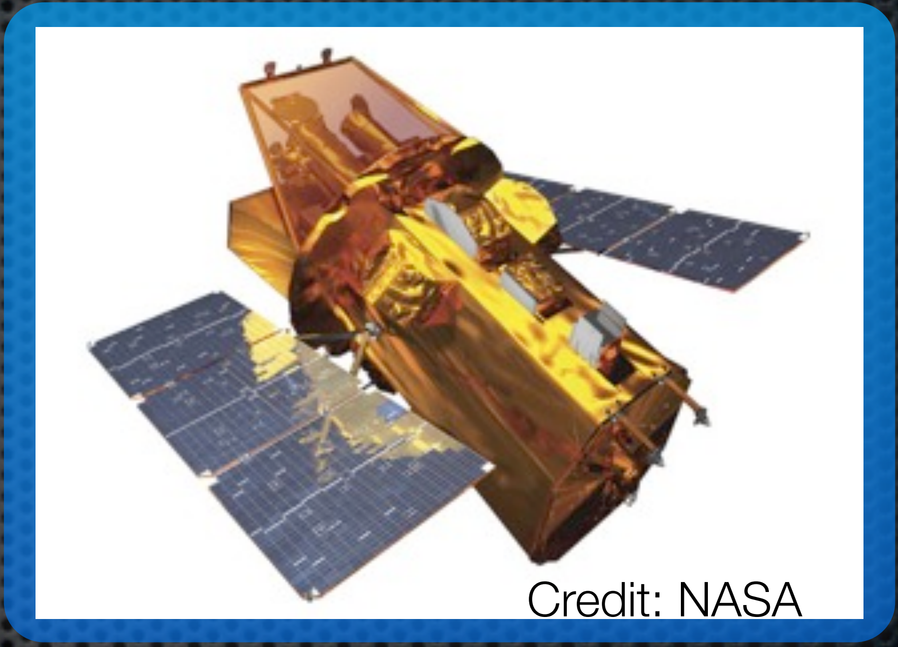
Two Types of EM+GW Searches



Allows for a more sensitive search by focusing on a short period of data and a single sky location.



Two Types of EM+GW Searches



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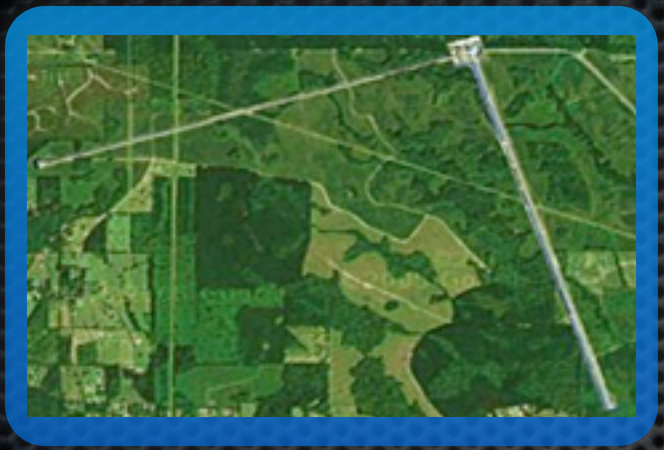
Two Types of EM+GW Searches



Allows for possibility of imaging corresponding EM signals as they occur.

LOOCUP

Credit: NASA

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Credit: ROTSE

GRB 070201: A success story

LIGO observations ruled out an inspiral progenitor in M31 at >99% confidence.* They allow a soft gamma repeater (SGR) progenitor.†

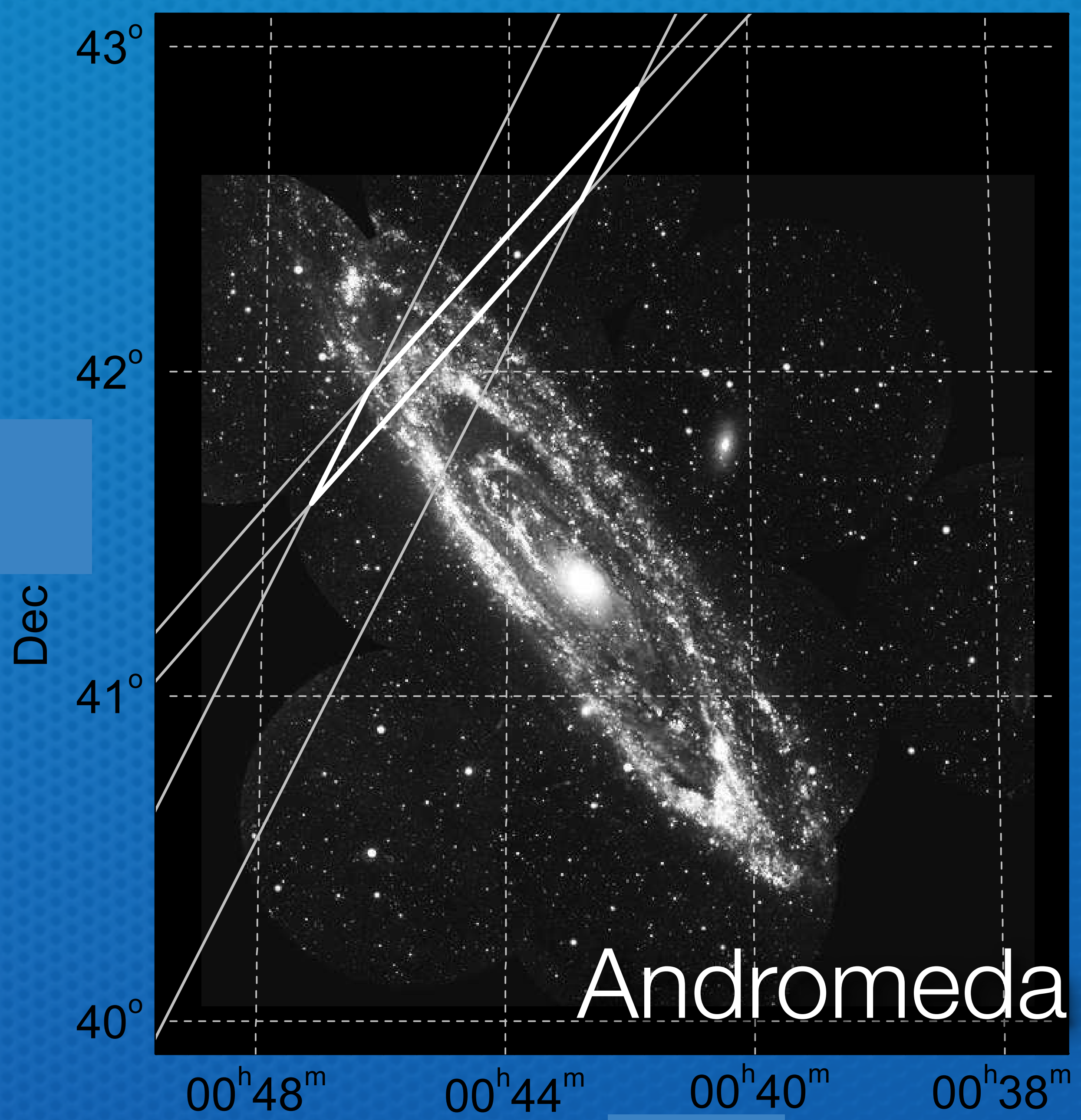

Image from
Mazets et al, ApJ 680, 545 (2008)

* Abbott et al, ApJ 681, 1419 (2008)

† Ofek et al, ApJ 681, 1464 (2008); Mazets et al, ApJ 680, 545 (2008)

GRB 070201: A success story

The Astrophysical Journal, 681:1464–1469, 2008 July 10

GRB 070201: A POSSIBLE SOFT GAMMA-RAY REPEATER IN M31[1]

E. O. Ofek,[2] M. Muno,[2] R. Quimby,[2] S. R. Kulkarni,[2] H. Stiele,[3] W. Pietsch,[3] E. Nakar,[2]
A. Gal-Yam,[4] A. Rau,[2] P. B. Cameron,[2] S. B. Cenko,[2] M. M. Kasliwal,[2]
D. B. Fox,[5] P. Chandra,[6,7] A. K. H. Kong,[8,9] and R. Barnard[10]
Received 2007 December 13; accepted 2008 February 18

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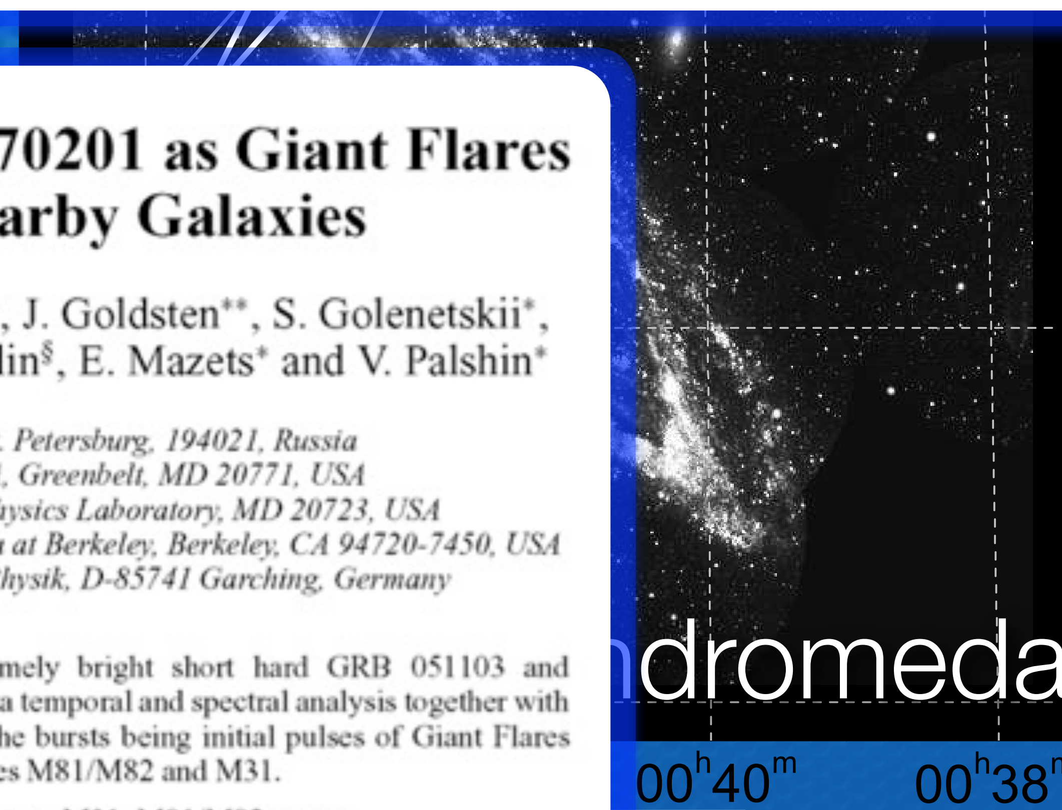
progenitor.†



GRB 051103 and GRB 070201 as Giant Flares from SGRs in Nearby Galaxies

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†Goddard Space Flight Center, NASA, Greenbelt, MD 20771, USA
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‡Space Sciences Laboratory, University of California at Berkeley, Berkeley, CA 94720-7450, USA
§Max-Plank-Institut für extraterrestrische Physik, D-85741 Garching, Germany

Abstract. The Konus-Wind observations of extremely bright short hard GRB 051103 and GRB 070201 are presented. Results of gamma-ray data temporal and spectral analysis together with IPN sources localization are bringing evidences of the bursts being initial pulses of Giant Flares from Soft Gamma-ray Repeaters in the nearby galaxies M81/M82 and M31.

Keywords: gamma-ray bursts, soft gamma-ray repeaters, M31, M81/M82 group
PACS: 95.85.Pw, 98.70.Rz, 98.56.Ne, 97.60.Jd

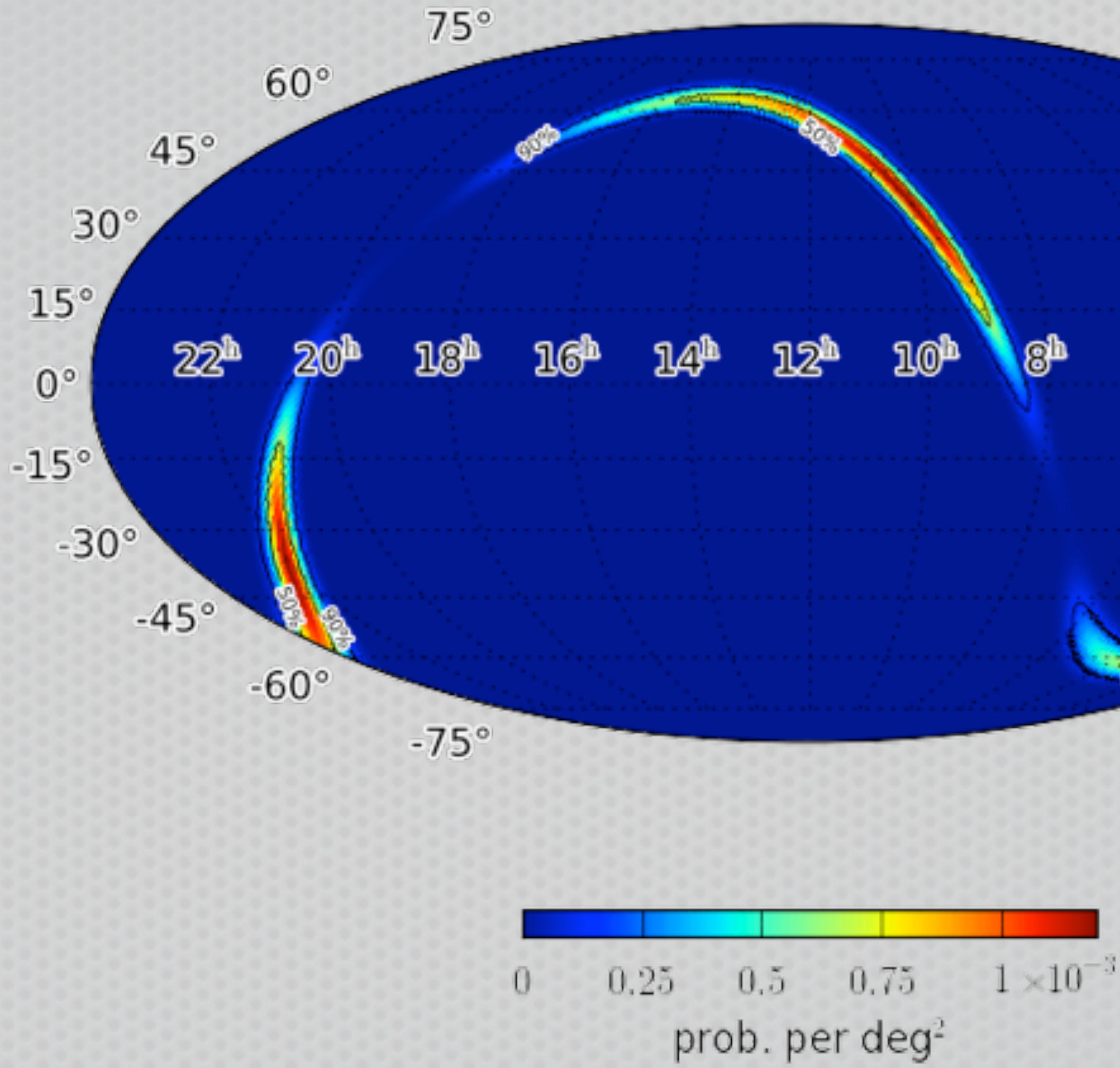
* Abbott et al, ApJ 68

† Ofek et al, ApJ 681, 1
Mazets et al, ApJ 68

Sky localization

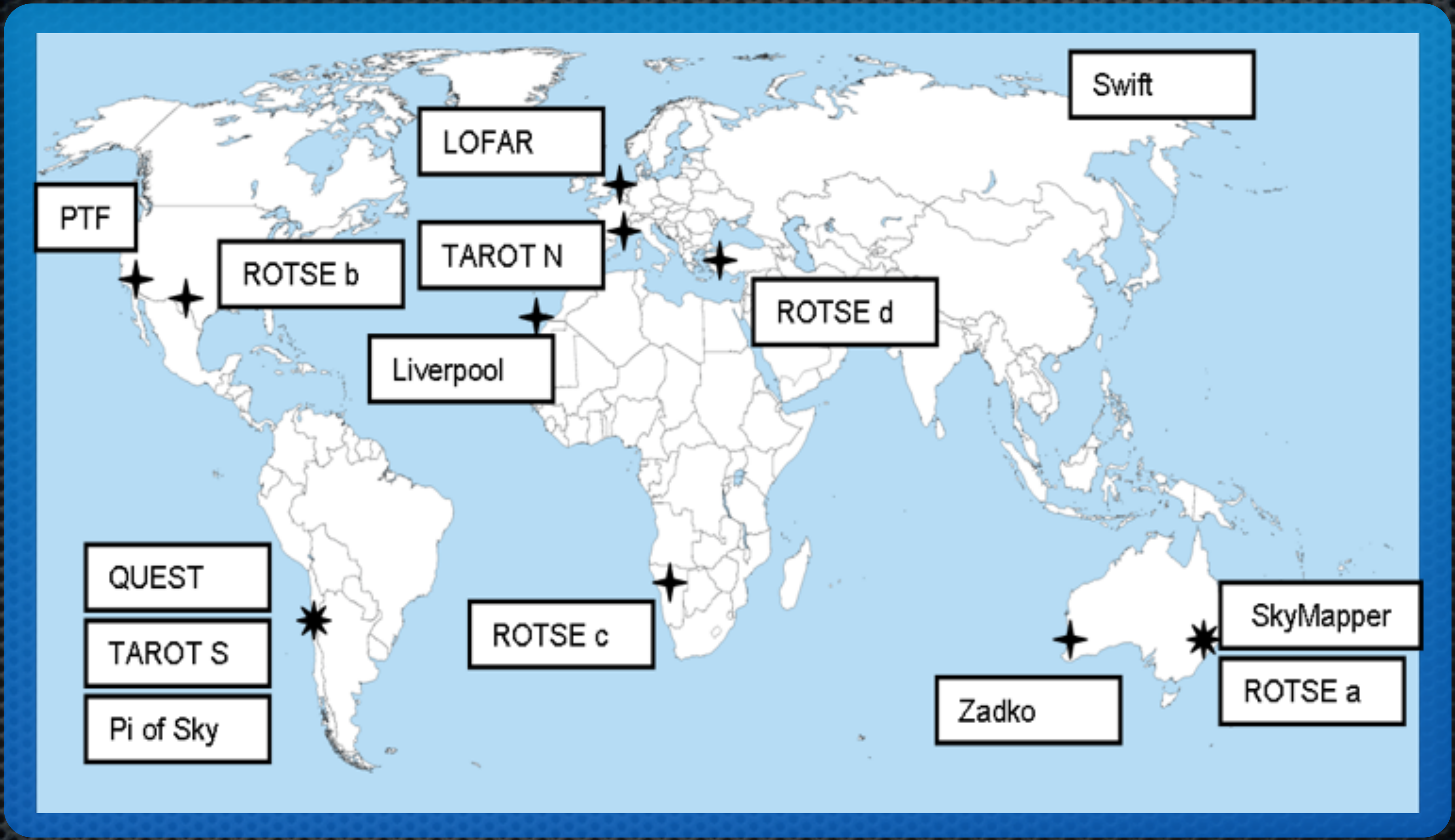
Use the time-delay between detector sites and the amplitude measured at each site to localize sources on the sky.

Typical Skymap



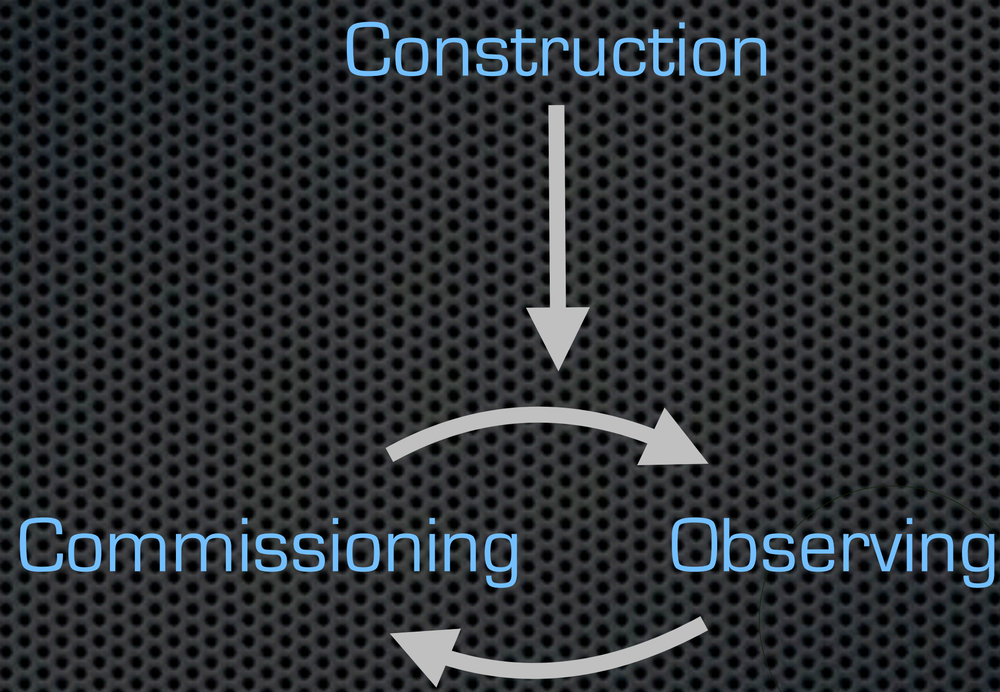
First Low-latency EM+GW Search

2009-2010

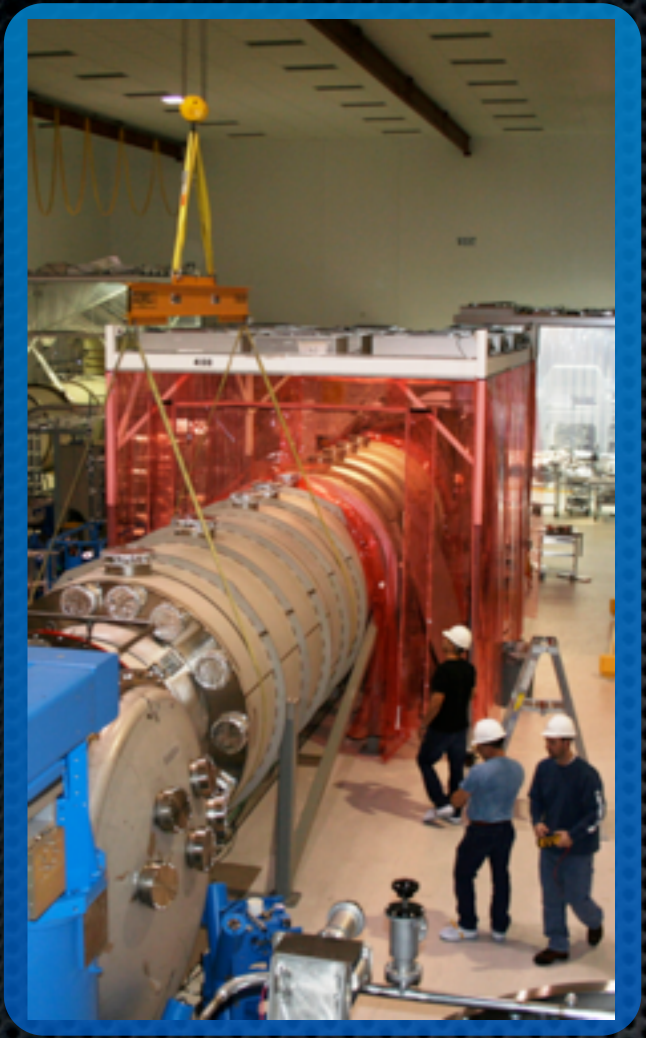


Abbott, et al, A&A 539, A124 (2012)
Abadie et al, A&A 541, A155 (2012)
Evans et al, ApJS 203, 28 (2012)

aLIGO & aVirgo

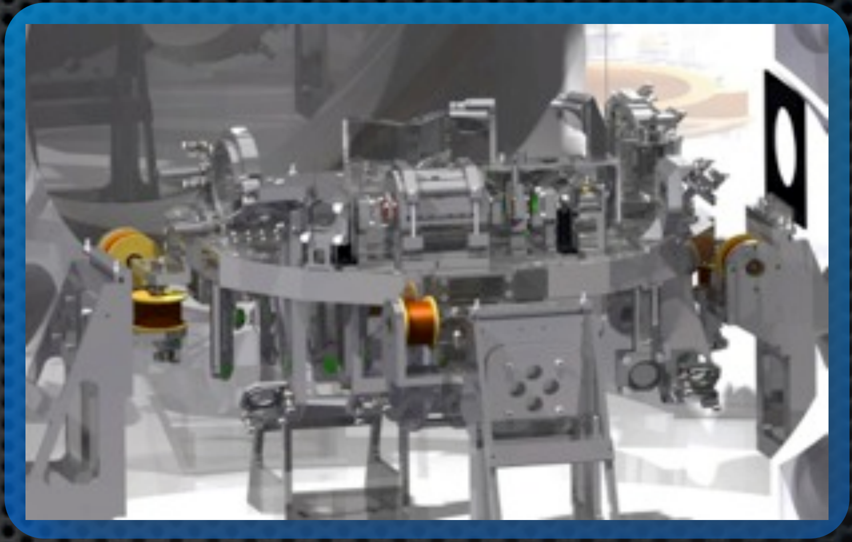


In Pictures



Placing aLIGO Input/Output Vacuum Tubes

Welding the LIGO Livingston X-arm Input Test Mass to Fused Silica Fibers

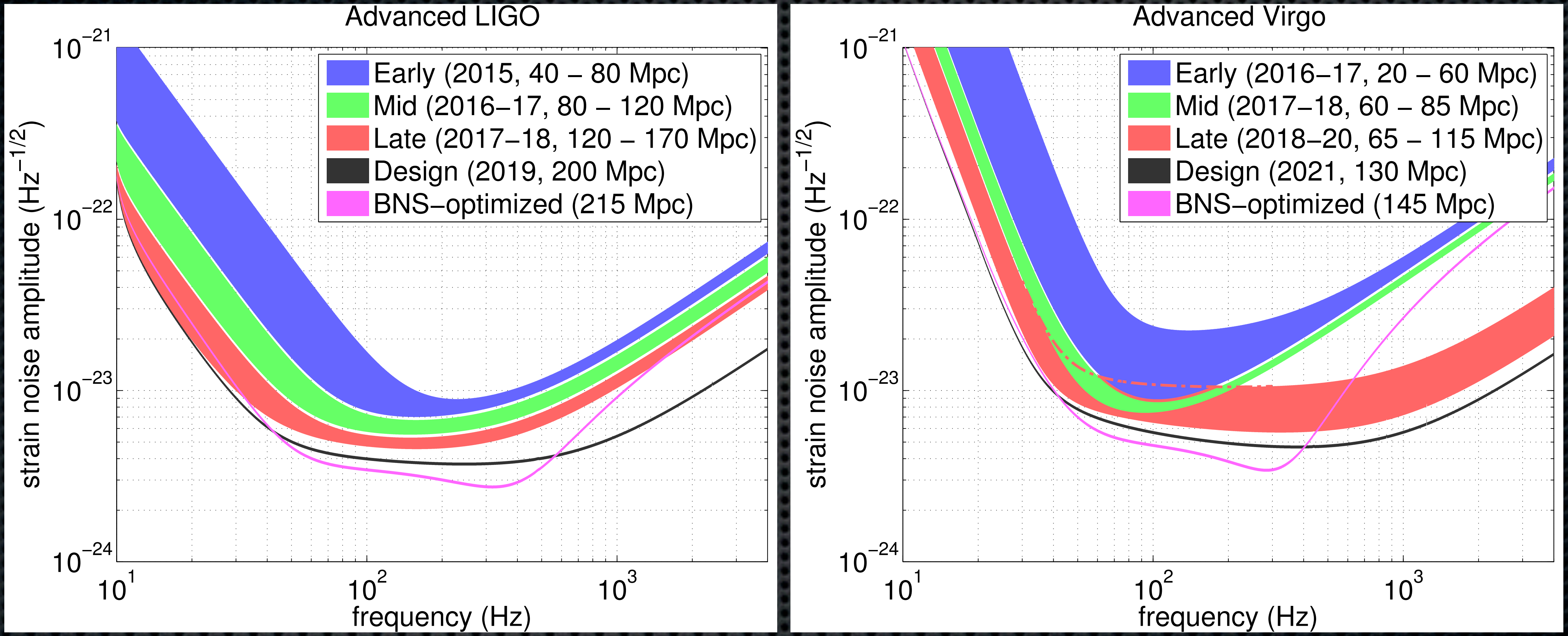


AdV input optics suspended bench

aLIGO transmission Monitor and Arm Length Stabilization System

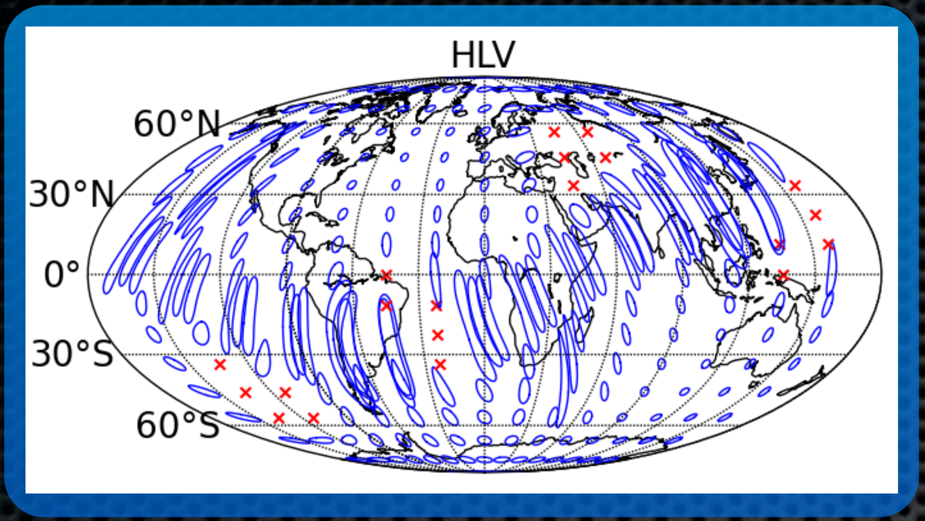
AdV test mass ring heater

Projected Sensitivity

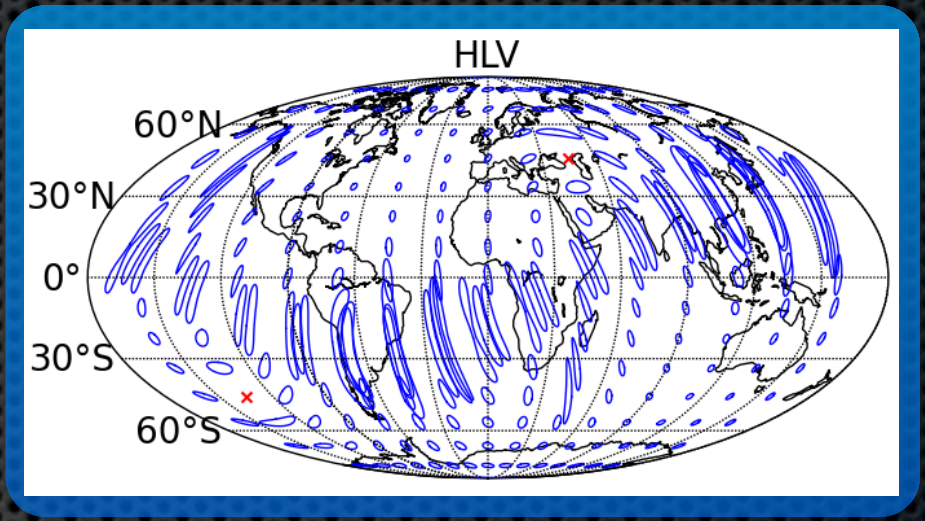


Aasai et al, arXiv:1304.0670 (2013)

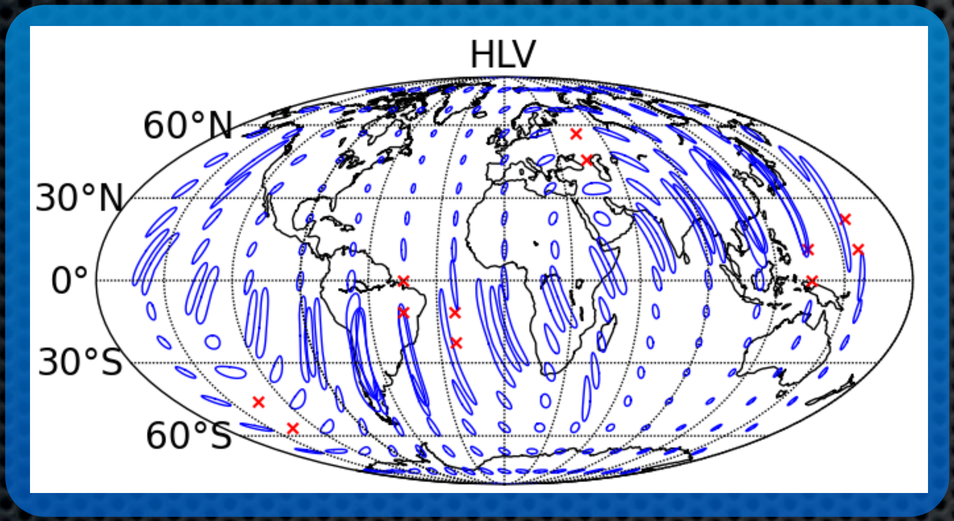
Evolution of Sky Localization



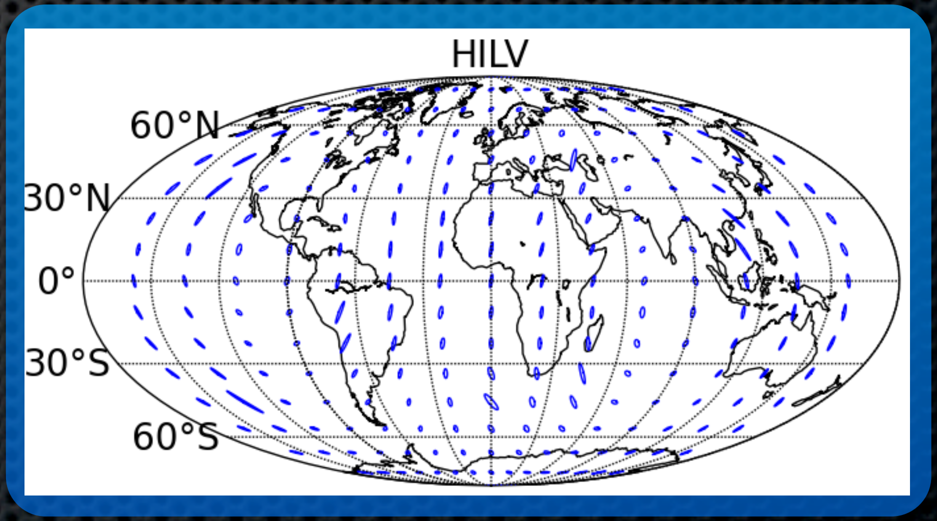
2016-17



2017-18



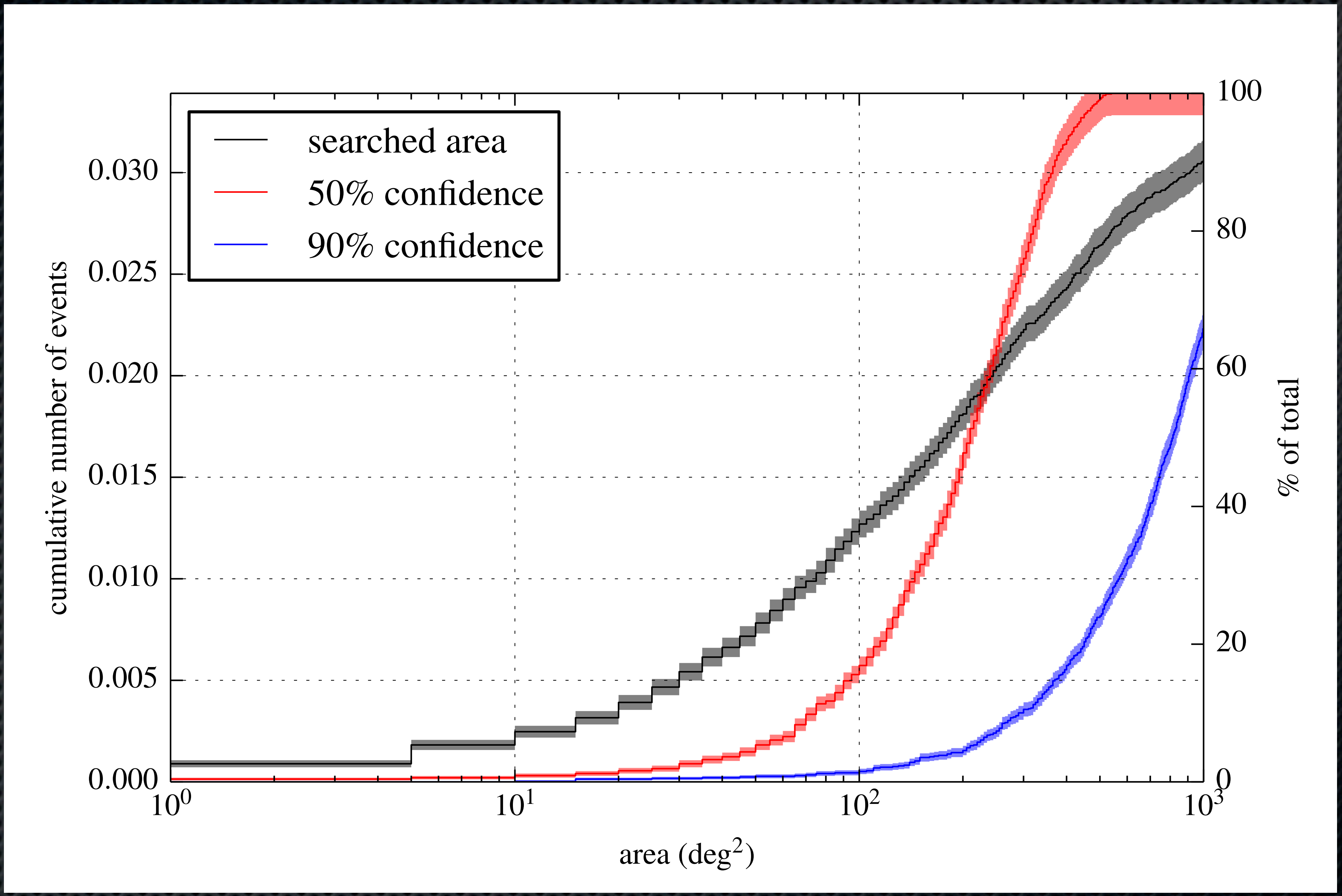
2019+



2022+

Aasai et al, arXiv:1304.0670 (2013)

In Numbers: Projection for 2015



Singer, **LP**, et al (in preparation)

Looking Forward

Epoch	Estimated Run Duration	$E_{\rm GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc) LIGO	Virgo	BNS Range (Mpc) LIGO	Virgo	Number of BNS Detections	% BNS Localized within $5\,\mathrm{deg}^2$	$20\,\mathrm{deg}^2$
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 70	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

Aasai et al, arXiv:1304.0670 (2013)

What's Next?

- aLIGO project ~87% complete. Includes most subsystem assembly, testing, and integration as well some of the more complex integrated testing (cf. Mike Landry's talk).
- aVirgo budget ~40% committed thus far. Early commissioning to start next year.
- On time for aLIGO observing run in 2015. aVirgo to follow in 2016.
- Discussions with the astronomy community regarding the details of future EM+GW searches and data sharing are underway.
- The first direct detection of gravitational waves and the era of gravitational wave astronomy are on the way!